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Research Article

Safety Assurance for Air Traffic Control Systems

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Abstract: **With rapid developments in science and technology, we now see the ubiquitous use of different types of safety-critical systems in our daily lives such as in avionics, consumer electronics, and medical systems. In such systems, unintentional design faults might result in injury or even death to human beings. To make sure that safety-critical systems are really safe, there is a need to verify them formally. In this paper we discuss about how to assure safety in Aircrafts and Air Traffic Control Systems (ATC). The technology in ATC needs to be modified to suit today's standards. The system safety approach to reduce risk is to anticipate accidents and their causes in before, the fact hazard analysis and to eliminate. This case study demonstrates how software engineering techniques can make a complex system dramatically simpler and flexible.**

I. INTRODUCTION

The air traffic control system, or ATC, is run by a government run organization called the Federal Aviation Administration in the United States. Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and in the air. The primary purpose of ATC systems worldwide is to separate aircraft to prevent collisions, to organize and expedite the flow of traffic, and to provide information and other support for pilots when able. In some countries, ATC may also play a security or defense role (as in the United States), or be run entirely by the military (as in Brazil).

Preventing collisions is referred to as separation, which is a term used to prevent aircraft from coming too close to each other by use of lateral, vertical and longitudinal separation minima; many aircraft now have collision avoidance systems installed to act as a backup to ATC observation and instructions. In addition to its primary function, the ATC can provide additional services such as providing information to pilots, weather and navigation information and NOTAMs (Notices to Airmen).

II. WORKING OF ATC

The process the ATC goes through every flight is simple. When an airplane takes off, the departure control, which is in the terminal radar control facility, TRACON, gives the airplane directions from a radar system to avoid other ascending and descending aircrafts, while giving updates on the plane's speed, altitude, and direction. This whole process only happens while the plane is in the TRACON's airspace, which is about 50 to 80 miles outside of the TRACON.

Once the plane has departed from the airspace of the TRACON, it switches over to the middle zone, where the air route traffic control center, ARTCC, takes over from the TRACON. Two air traffic controllers now monitor the plane, called the radar associate controller. This controller receives flight plan data prior to the plane's arrival. The associate controller works with the radar controller in charge of that sector. The radar controller is in charge of all air-to-ground communication, maintains safe separation of aircraft within the sector and coordinates activities with other sectors and/or centers.

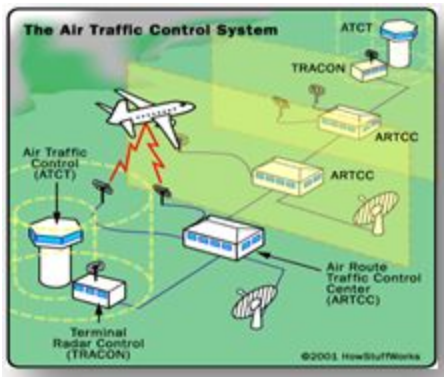

Fig: The Air Traffic Control System

The radar associate controller must also monitor all the airways and airspace at altitudes of above 7320 meters. In the very middle of the flight, the plane is provided weather and air traffic information. There are many sectors in which all of this happens. Just like when the airplane left the airspace of the TRACON, every ARTCC has its own airspace, and when an airplane flies out of one of the controller's airspace, it is switched to another one, until it reaches the other airport, where it switches back to another TRACON and the plane descends.

III. TERMINOLOGY

- Safety critical system – "The software used in the design of physical streams and structures, whose failure can have massive, life-threatening impact."
- Hazard – "An intrinsic property or condition that has the potential to cause an accident."
- Reliability – "The probability that a system, subsystem, or component will perform its intended function for a specified period of time under normal condition."
- Risk - "The combination of the probability of an abnormal event or failure and the consequences of that event or failure to a system's operator, users, or its environment."
- Accident – "An undesired consequence inflicting injury to person or damage to property in the process"
- Uncertainty –"Measure of knowledge limits in a technical area" Safety critical systems are designed to prevent accidents and establish reliability by minimizing risk and eliminating hazards and uncertainty.
- Reliability: Reliability is the characteristic of an item expressed by the probability that it will perform its required function in the specified manner over a given time period and under specified or assumed conditions

IV. TECHNOLOGY

Many technologies are used in air traffic control systems –

Flight Data Processing System :

It manages all the flight plan related data, and incorporates in a low or high degree the information of the track, once the correlation between them (flight plan and track) is established.

Short Term Conflict Alert :

- That checks possible conflicting trajectories in a time horizon of about 2 or 3 and alerts the controller prior to the loss of separation.

- The algorithms used may also provide in some systems a possible vectoring solution, that is, the manner in which to turn, descend, or climb the aircraft in order to avoid infringing the minimum safety distance or altitude clearance.

Minimum Safe Altitude Warning :

It is a tool that alerts the controller if an aircraft appears to be flying too low to the ground or will impact terrain based on its current altitude and heading.

System Coordination:

It is to enable controller to negotiate the release of flights from one sector to another.

Area Penetration Warning:

It is to inform a controller that a flight will penetrate a restricted area.

Arrival and Departure Manager

This helps sequence of takeoff and landing of an aircraft.

Departure Manager (DMAN):

A system used for the ATC at airports, that calculates a planned departure flow with the goal to maintain an optimal throughput at the runway, reduce queuing at holding point and distribute the information to various stakeholders at the airport (i.e. the airline, ground handling and Air Traffic Control (ATC)).

Arrival Manager (AMAN):

This system is used for the ATC at airports, that calculates a planned Arrival flow with the goal to maintain an optimal throughput at the runway, reduce arrival queuing and distribute the information to various stakeholders.

passive Final Approach Spacing Tool (pFAST):

This is a CTAS tool, which provides runway assignment and sequence number advisories to terminal controllers to improve the arrival rate at congested airports. pFAST was deployed and operational at five US TRACONs before being cancelled.

Converging Runway Display Aid (CRDA):

This enables Approach controllers to run two final approaches that intersect and make sure that go around are minimized.

Center TRACON Automation System (CTAS):

This is a suite of tools to help controllers manage air traffic flow at large airports. CTAS increases the landing rate through automated planning.

Traffic Management Advisor (TMA):

CTAS contains two primary tools. Low altitude controllers who manage the airspace near an airport use Final Approach Spacing Tool (FAST) while high altitude controllers who manage aircraft further away use the Traffic Management Advisor (TMA).TMA is a tool, which en-route decision support tool that automates time based metering solutions to provide an upper limit of aircraft to a TRACON from the Center over a set period of time.

ADS-B:

Automatic Dependent Surveillance Broadcast is an Automatic Dependent Surveillance Broadcast that provides a data downlink of various flight parameters to air traffic control systems via the Transponder (1090 MHz) and reception of those data by other aircraft in the vicinity.

V. PROBLEMS IN CURRENT ATC

The technology used with the ATC is old and it needs to be replaced to suit today's standards of technology. The component of a deployed air traffic control system written in about 80,000 lines of C++ code, is now replaced with new version in Java about one-fifth of the size, and demonstrated its primary functions. Although this existing version only performs the original component's essential functions, it could be extended to cover the full functionality without substantially changing its architecture.

There are also other views to this whole new plan. Some say that the ATC is fine as it is, and that upgrading it is redundant. However, if the ATC is not upgraded, the system will slowly degenerate, because the radio sets being used currently will become more and more outdated as time passes.

There are many fundamental problems with the ATC. The way the air traffic control system worked back in the 1960s does not work today. The first and foremost problem with the ATC is the technology used to support it.

The main issue with the ATC is the excessive amount of air traffic and how unsafe the airspace is with so many airplanes out there at once. Another minor issue, but still a factor in the affair of air traffic is weather. Often times a thunderstorm will cause multiple aircrafts to fly in a straight line through a single designated path in the thunderstorm. These problems must have some solutions, since there is no such thing as a problem without a solution in its hands.

Others may say that if a new system that relies more on technology and less on the pilot is used, pilots will then become less professional and may not be capable enough to handle a plane in an emergency. While this is somewhat true, pilots could be trained to handle new technology as well as be trained to use the old technology in an emergency.

The solutions to these problems are very straightforward, but there is one very large obstacle that blocks the whole path, money. The United States national debt right now over 12 trillion dollars! Obviously, trying to upgrade the system would only add to the ever-increasing national debt. The solution to this problem is to support all the upgraded ATC technology with some market based infrastructure.

VI. PROPOSED CHANGES IN TECHNOLOGY

Nowadays, each and every organization tries to adopt the new technologies in order to beat all the other companies and to reach the peak of the innovative world.

Till now we have seen so many things like technologies used, terminology, working and various systems used in Air Traffic control systems.

But is these new and innovative generations will this existing infrastructure is sufficient?? No.
So the technological developments should be made and the equipments should be redesigned in Air Traffic Control systems to come out with a better result.

The first step to improve this system is very straightforward now. Replace all of the old technology with newer and more understood technology that goes by everyone's standards.

- The existing system of Air Traffic Controller contains Radars and Radio systems at each and every station to handle the flight responsibilities. Maintaining these systems will cause some problems to the avionics industry. For the radars and radio problems, they can be replaced with things such as a GPS-based system, to eliminate any use of radios and radars.

- The day-to-day problems faced by the air traffic control system are primarily related to the amount of air traffic demand placed on the system. Several factors dictate the amount of traffic that can land at an airport in a given amount of time. Each landing aircraft must touchdown, slow, and exit the

runway before the next crosses the end of the runway.

This process requires at least one and up to four minutes for each aircraft. Allowing for departures between arrivals, each runway can thus handle about 30 arrivals per hour. A large airport with two arrival runways can handle about 60 arrivals per hour in good weather.

Problems begin when *airlines* schedule more arrivals into an airport than can be physically handled, or when delays elsewhere cause groups of aircraft that would otherwise be separated in time to arrive simultaneously. The increase of congestion in airspace can also be solved by the new Satellite tracking device, since it will give "turn-by-turn" guides from one airport to another.

- Another solution to this problem could be to replace the older jets with newer and more fuel efficient jets that can get through the sky faster and without as much struggle as older jets.

- The Replacement of Source code with the advanced versions of programming languages will work well because the new version provide so many extra features to the system which will increase the efficient working of ATC so that we can replace the usage of languages of the software design.

- Beyond runway capacity issues, weather is a major factor in traffic capacity. Rain, ice or snow on the runway cause landing aircraft to take longer to slow and exit, thus reducing the safe arrival rate and requiring more space between landing aircraft. In Area Control Centers, a major weather problem is *thunderstorms*, which present a variety of hazards to aircraft.

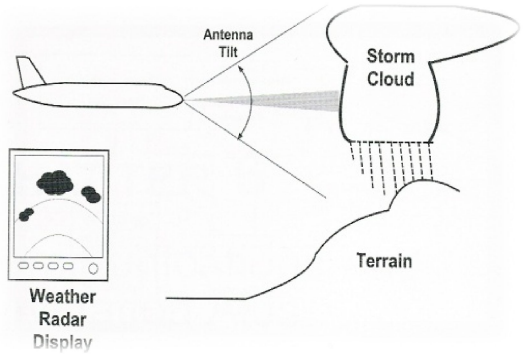

Figure: Weather Radar

- Aircraft will deviate around storms, reducing the capacity of the en-route system by requiring more space per aircraft, or causing congestion as many aircraft try to move through a single hole in a line of thunderstorms. The problem of Weather cannot really be solved, since weather is a natural thing. But we can avoid those by using *flight progress strips*.

- There are not only problems with the ATC however; there are also some fundamental problems with the government's solution to the air traffic problem.

VII. CONCLUSION

The new design is not only simpler but also more flexible, easier to analyze and easier to tune. The redesigning of Air Traffic Control System with the new technology approaches will be more effective and advantageous.

The ATC is a government run organization that controls all air traffic. The ATC has many problems - The technology is outdated, airways are congested, weather congests the airways even more.

All these problems have solutions - Replace the old technology with the latest upgrade of GPS system and satellite technology, Implement the technology so that airways become less congested. While replacing the older jets with newer more fuel-efficient ones, Use satellite technology to get quick weather forecasts and change routes quickly to avoid storms, Money is a big issue when it comes down to upgrading the ATC, Create some market-based infrastructure to back up the entire aviation infrastructure, Add a few taxes here and there to airplane tickets, Next Gen 2018 is a government-run project that will upgrade the ATC by around 2018, There are many fundamental problems with this, There is no market based infrastructure to back up the upgrades, The technology that will be used to update the system might be outdated by 2018.

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